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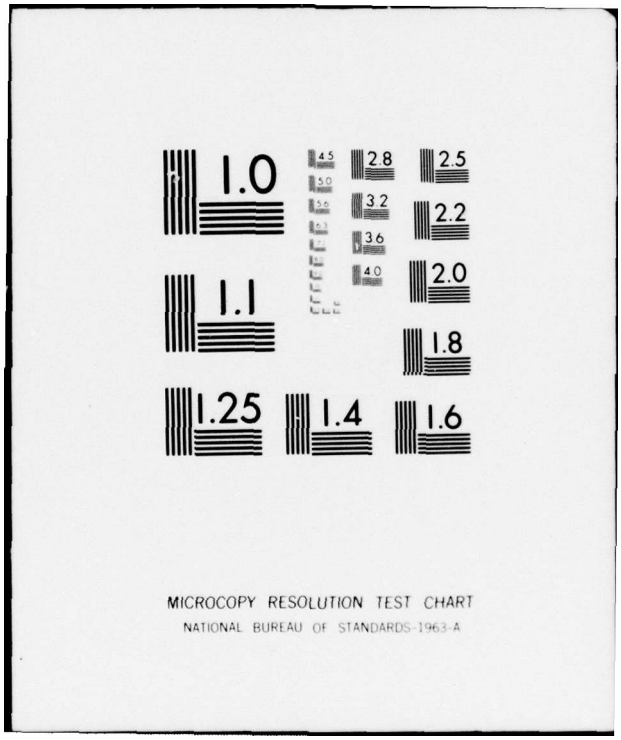
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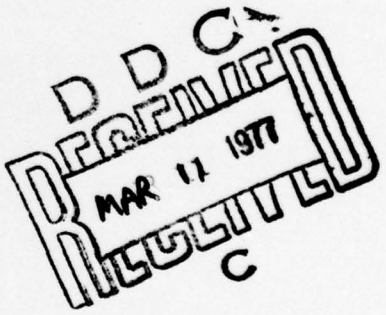
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND



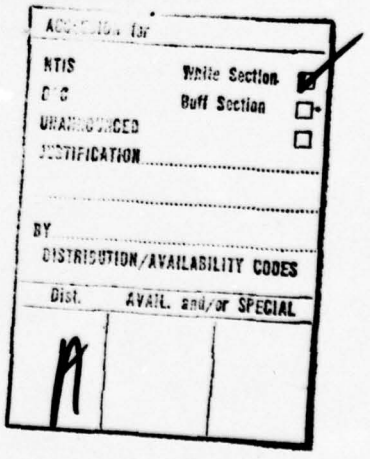
1 AUGUST – 31 OCTOBER 1976

ISSUED 23 DECEMBER 1976

LEXINGTON MASSACHUSETTS

INTRODUCTION

This Quarterly Technical Summary covers the period 1 August through 31 October 1976. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.



CONTENTS

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 August through 31 October 1976 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Education Technology	Bureau of Mines, ARPA/HRRO
Network Speech Processing	OSD-DCA
Digital Voice Processing	AF/ESD
Packet Speech	ARPA/IPTO
Communications Adaptive Internetting	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC

M. A. Herlin
Head, Division 2

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Associate Head

DIGITAL COMPUTERS
GROUP 23

I. INTRODUCTION

The set of custom LSI circuits for a speech synthesizer is nearly complete. Design of a very high-speed serial-to-parallel converter utilizing poly-ox dielectric isolation has begun, and progress was made on fabrication of an MNOS memory test device.

II. APPLICATIONS

A. Gate Array Custom Circuits

The status of the five custom ECL gate array circuits for the Lincoln Integrated Speech Synthesizer (LISSYN) is as follows:

(1) Four-phase clock generator – good devices have been packaged and operated in the LISSYN circuit board. One device operated correctly up to a clock frequency of 120 MHz.

(2) 4-bit arithmetic-logic unit – four good devices have been packaged. Delay measurements on several critical paths show delays of about 2 nsec/gate which should be adequate for the LISSYN design goal of a 50-nsec cycle time.

(3) 4-bit register transfer unit – four good devices have been packaged and others are being delay tested.

(4) Control A – good devices have been produced at wafer test and are being packaged.

(5) Control B – devices are being tested but there were no good ones in the first lot.

For devices (2), (3), and (4) the only errors in the first mask sets were two missing lines and one short. The missing lines were generated on the working masks using the laser mask-zapper, and the short was removed on the chip. Thus, the designs were proved without waiting for new-mask generation.

B. Sequential Radar Data Memory Circuit

The speed-critical part of this proposed memory circuit is a shift register. The test-chip shift register, with dissipation of 5 mW per master-slave flip-flop stage, has been operated successfully at clock frequencies up to the 200-MHz limit imposed by test apparatus. System studies have shown that it is now possible to make from commercially available components a serial memory system that will accept data at a rate of 250 MHz with only slightly higher parts count than one made with the proposed custom integrated circuit. The limiting factor to extending memory performance is the serial-to-parallel converter. We are therefore focusing our effort on construction of an 8-bit S/P converter with output holding register for serial input rates up to 1.0 GHz using the poly-ox isolation process. This requires (1) characterizing and

improving the poly-ox process, (2) designing, fabricating, and testing of process evaluation devices, (3) designing, fabricating, and testing of the serial-to-parallel converter chip, and (4) developing 1.0-GHz test equipment.

Circuit design is nearly complete. Inputs for serial data, high-speed clock and a parallel-transfer-enabling signal, and outputs from the last bit of the shift register and from the 8-bit holding register are provided. External signals will all be Emitter-Coupled-Logic compatible. Most internal logic will use low-level differential logic circuits. Preliminary circuit layout has been started.

C. MNOS Capacitor Memory Arrays

A completely undecoded 30 × 30 MNOS capacitor array has been designed and fabricated in order to test a resistor-diode partial-decoding circuit off chip. The first wafers containing these arrays are currently undergoing preliminary testing prior to packaging. A resistor-diode AND gate circuit has been breadboarded in order to test this partial decoding technique on the packaged 30 × 30 MNOS test arrays.

Experiments have been carried out using a transresistance amplifier to sense the C-V curves of MNOS capacitors. This has lessened the effect of stray capacitance-to-ground on the risetime of the output signal, thus allowing an increase in magnitude of the output signal although a significant amount of amplifier noise is also added.

III. INTEGRATED CIRCUIT PROCESSING

A. Gate Array Device Yields

Three additional ECL gate array circuits were processed this quarter with gratifying yield results. The devices were the 4-bit arithmetic-logic unit (ALU), a 4-bit register transfer unit (RT), and the Control A. The first two devices are quite complex, and initial test results indicated that higher common emitter current gains were required. After the emitter process was revised to achieve higher current gains, we obtained wafer-probe test yields of 6.0 and 18.5 percent for the ALU and RT, respectively. In addition, the first Control A run provided three functional devices, which is equivalent to a yield of 4.7 percent.

B. Self-Aligned Transistors

Transistors have been fabricated where the base and emitter are implanted sequentially through the same oxide window with a single anneal. Also, the annealing cycle has been modified to a low-temperature recrystallization treatment to anneal out the structural damage of the implant, followed by a moderate temperature step to activate and diffuse the implanted species to the final desired profile.

Two major problems have been experienced, the first being arsenic-metal contact problems and the second being low betas at low current and leaky emitter-base junctions, probably due to excessive recombination in the emitter-base junction. Solutions to both these problems are being investigated with some success.

C. Poly-Ox Dielectric Isolation

ECL gate chains have been successfully fabricated using the poly-ox dielectric isolation process. Speed measurements await packaging. The main yield detractor of these circuits lies

not in the isolation but in the transistor performance anomalies similar to those experienced in the self-aligned-transistor work.

A new mask set and processing sequence for the poly-ox process have been developed which feature (1) low-resistance collector sinkers, (2) field oxide between collector contact and base, (3) field oxide delineation of resistors in polysilicon, and (4) independent doping of base inserts and polyresistors. Preliminary design rules for poly-ox process devices have been formulated. New process features are being evaluated.

Masks have been designed and fabricated for a poly-ox evaluation circuit, and wafer processing has begun. These circuits will be used to measure sheet resistivities, breakdown, and capacitance of the various diffused or implanted layers, to measure parameters of typical resistors and transistors, to evaluate device yield, and to refine the process and its design rules. Test equipment and programs are being designed.

D. Ion Implanter

A 200-keV ion implanter has been installed. It has the capability of implanting As, P, and B with beam currents greater than 100 μA and has an automatic-wafer-handling end station.

IV. DESIGN, ANALYSIS, AND TESTING

A. Endurance of MNOS Memories

A model to account for the finite "endurance" of MNOS memory elements is being developed. The model is based on the accumulation of positive charge in the oxide layer due to a high concentration of bridging oxygen vacancies in the oxide near the Si/SiO_2 interface which act as hole traps.

B. Gate Array Design Manual

A new version of the manual contains logic diagrams, circuit diagrams, and cell layout/wiring diagrams for the 42 different cells which now exist in the library.

C. I^2L Test Set

The I^2L "test device" is a 4-terminal circuit containing a multi-collector NPN and a PNP transistor. A special relay box has been designed to allow interconnecting groups of leads so that the net result is a 3-terminal device which can be evaluated by our standard transistor test set.

D. Testing Computer

Core memories were salvaged from the TX-2 computer and interfaced to the testing minicomputer to provide a 128K word backing-store for the virtual memory, replacing a fixed-head-disk. New software was installed. Testing programs now execute 2 to 6 times faster.

COMPUTER SYSTEMS
GROUP 28

Twelve IBM 3350 fixed-medium-disk storage drives replaced ten IBM 3330 interchangeable medium drives during this quarter. The exchange increased both on-line storage capacity and data transfer rate by 50 percent while holding costs almost equal. New versions of the VM time-sharing system and the VS batch-processing system were installed to support the new configuration.

A considerable effort was put into revising the backup procedures for the 3350 drives. The general procedure is to make a complete tape copy of each disk once a week, and a partial copy of only changed files on a daily basis. The latter, known as an incremental backup, is considerably faster than a complete backup because normal daily activity affects only a relatively small amount of the total data in storage. Nevertheless, the search for changed data must be thorough and more efficient than simply copying everything. Recovery of data is also more complex with incremental backups because a number of tapes in precise order are involved. The importance of backups increases as the amount, and therefore the vulnerability to loss, of on-line data increases. These new backup procedures are now in regular operation. The recovery procedures have been tested, but not yet needed since the performance of the new drives has been excellent, with not even one correctable error encountered.

A command-driven subroutine has been developed to support data transmission using IBM's Binary Synchronous Communications procedures. This facility assists users in developing special applications which employ this protocol. The first such application, now in development, involves very long-distance data acquisition over a land line and communications satellite link. Early problems in this application relate to the unusually long delays in the bi-synch transmission/response cycles resulting from the very long data paths.

A high-level subroutine package has been developed to function as an ARPA-Network access method for Fortran or PL/I applications programs. Calls at the level of OPEN, READ, WRITE, or CLOSE are similar in concept to like calls available in other input/output access methods. This permits a user program to access a distant network facility with the same kind of programming simplicity as would be required for a local tape or disk file.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 August through 31 October 1976. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army (BMDATC), ARPA (MSO, IPTO), NSF, and ERDA.

A. L. McWhorter
Head, Division 8

I. Melngailis
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 August through 15 November 1976

PUBLISHED REPORTS

Journal Articles

JA No.			
4036	Ferromagnetism	J. B. Goodenough	Estratto dal Vol. V della Enciclopedia della Chimica (Uses Edizioni Scientifiche, Firenze, 1976), p. 357
4615	Impurity Gettering in Semi-insulating Gallium Arsenide Using Ion Implantation Damage	C. O. Bozler J. P. Donnelly W. T. Lindley R. A. Reynolds*	Appl. Phys. Lett. 29, 698 (1976)
4618	Transient InSb Spin-Flip Laser – A Measurement of T_1	S. R. J. Brueck A. Mooradian	Opt. Commun. 18, 539 (1976)
4623	High-Efficiency High-Average-Power Second-Harmonic Generation with $CdGeAs_2$	N. Menyuk G. W. Iseler A. Mooradian	Appl. Phys. Lett. 29, 422 (1976)
4636	Selective Black Absorbers Using MgO/Au Cermet Films	J. C. C. Fan P. M. Zavracky	Appl. Phys. Lett. 29, 478 (1976)
4641	Distributed Feedback $Pb_{1-x}Sn_xTe$ Double-Heterostructure Lasers	J. N. Walpole A. R. Calawa S. R. Chinn S. H. Groves T. C. Harman	Appl. Phys. Lett. 29, 307 (1976), DDC AD-A031649
4643	Direct Optically Pumped Multiwavelength CO_2 Laser	M. I. Buchwald* C. R. Jones* H. R. Fetterman H. R. Schlossberg*	Appl. Phys. Lett. 29, 300 (1976)
4678	GaAs $p^+n^-n^+$ Directional-Coupler Switch	F. J. Leonberger J. P. Donnelly C. O. Bozler	Appl. Phys. Lett. 29, 652 (1976)

Meeting Speeches

MS No.			
4067	Recent Advances in Tunable Lasers	A. Mooradian	Sov. J. Quant. Electron. 6, 420 (1976)

* Author not at Lincoln Laboratory.

MS No.			
4169	Ion Beam Etching	H. I. Smith	Proceedings of Symposium on Etching and Pattern Definition (The Electrochemical Society, Princeton, New Jersey, 1976), pp. 133-143
4205	Design of Reflective-Array Surface Wave Devices	J. Melngailis R. C. Williamson J. Holtham R. C. M. Li	Wave Electronics 2, 177 (1976)

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.			
4621	Minority Carriers in Graphite and the H-Point Magnetoreflection Spectra	W. W. Toy* M. S. Dresselhaus* G. Dresselhaus	Accepted by Phys. Rev. B
4647	Multiple-Energy Proton Bombardment in n^+-GaAs	J. P. Donnelly F. J. Leonberger	Accepted by Solid-State Electron.
4681	Preparation and Properties of PbS Crystals with Low Carrier Concentrations	T. C. Harman A. J. Strauss	Accepted by J. Electron. Mater.
MS-4280	CdTe Optical Waveguide Modulators	D. L. Spears A. J. Strauss	Accepted by J. Physique

Meeting Speeches†

MS No.			
4062A	GaAs/GaAlAs and GaInAsP/InP DH Diode Lasers Grown from Supercooled Solutions	J. J. Hsieh	Seminar, RCA Laboratories, Princeton, New Jersey, 12 August 1976
4124	Analog Memory Correlators for Radar Signal Processing	E. Stern	AGARD Symposium, The Hague, Netherlands, 14-17 June 1976
4124A	Wideband Signal Processing with Acoustoelectric SAW Devices	R. C. Williamson	Symposium on Impact of New Technologies in Signal Processing, Aviemore, Scotland, 21-24 September 1976

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
4140C,D	Photoelectrolysis of Water	J. G. Mavroides	Colloquium on Photoelectrolysis, Johns Hopkins University, 8 October 1976; Greater Washington Physics Colloquium, Washington, D. C., 7 October 1976
4177D	Sputtered Films for Solar Energy Applications	J. C. C. Fan	New England ISHM Technical Symposium, Woburn, Massachusetts, 21 September 1976
4177E	Wavelength-Selective Surfaces for Solar Energy Utilization	J. C. C. Fan	Symposium on Optical, Electro-Optical, Laser and Photographic Technology, San Diego, 23-27 August 1976
4230A	$In_xGa_{1-x}As_yP_{1-y}$/InP Double-Heterostructure Lasers	J. A. Rossi J. J. Hsieh J. P. Donnelly	1976 North American Symposium on Gallium Arsenide and Related Compounds, St. Louis, Missouri, 26-29 September 1976
4295	Thickness of InP Layers Grown by LPE from Supercooled Solutions	J. J. Hsieh	
4296	Ion Implanted Lo-Hi-Lo Annular GaAs IMPATT Diodes	R. A. Murphy C. O. Bozler J. P. Donnelly R. W. Laton G. A. Lincoln R. W. Sudbury W. T. Lindley L. Lowe* M. Deane*	
4298	Conditions for Lattice-Matching in the LPE Growth of GaInAsP Layers on InP Substrates	J. J. Hsieh M. C. Finn J. A. Rossi	
4302	Ion Implantation in GaAs	J. P. Donnelly	
4230B	$In_xGa_{1-x}As_yP_{1-y}$/InP Double-Heterostructure Lasers	J. J. Hsieh J. A. Rossi J. P. Donnelly	IEEE Semiconductor Laser Conference, Nemu-no-sato, Mie, Japan, 6-8 September 1976
4230C	1.2 μm cw, Room-Temperature GaInAsP/InP DH Diode Lasers	J. J. Hsieh	Seminar, Bell Laboratories, Holmdel, New Jersey, 4 August 1976
4261	Studies of Surface Defect States on TiO_2: Two-Dimensional Surface Phases	V. E. Henrich G. Dresselhaus H. J. Zeiger	XIII International Conference on the Physics of Semiconductors, Rome, Italy, 30 August – 3 September 1976

* Author not at Lincoln Laboratory.

MS No.			
4263A	Theory of Resonant Raman Scattering from Magnetic Excitons in Europium Chalcogenides	S. A. Safran* G. Dresselhaus M. S. Dresselhaus* B. Lax*	XIII International Conference on the Physics of Semiconductors, Rome, Italy, 30 August – 3 September 1976
4263	Theory of Resonant Raman Scattering from Magnetic Excitons in Europium Chalcogenides	S. A. Safran* G. Dresselhaus M. S. Dresselhaus* B. Lax*	International Conference on Magneto-Optics, Zurich, Switzerland, 1-3 September 1976
4265B	High-Nd-Concentration Mini-Lasers and Laser Materials	S. R. Chinn	Seminar, Philips Research Laboratories, Briarcliff Manor, New York, 31 August 1976
4271	X-Ray Lithography	H. I. Smith	1976 International Conference on Solid State Devices, Tokyo, 1-3 September 1976
4274A	Tunable Infrared Lasers and Their Applications	P. L. Kelley	1976 Fall Meeting, Optical Society of America, Tucson, Arizona, 18-22 October 1976
4285	The Influence of Semiconductor Properties on Photoelectrolysis of Water	D. I. Tchernev	International Conference on the Photochemical Conversion and Storage of Solar Energy, London, Ontario, Canada, 24-28 August 1976
4290	Double Reticle Method of Eliminating Repeated Defects in LSI Masks	T. O. Herndon D. L. Smythe, Jr.	INTERFACE '76 Microelectronics Seminar, Monterey, California, 3-6 October 1976
4318	Suppression of Bulk-Wave Scattering Loss in SAW Resonators	J. A. Alusow R. C. M. Li R. C. Williamson	1976 IEEE Ultrasonics Symposium, Annapolis, Maryland, 29 September – 1 October 1976
4319	Convolvers for DPSK Demodulation of Spread Spectrum Signals	J. H. Cafarella S. A. Reible E. Stern R. W. Ralston	
4320	A Continuously Variable Delay Line System	V. S. Dolat R. C. Williamson	
4332	Lincoln Laboratory Program on Thin-Film Photovoltaics	H. J. Zeiger	ERDA Solar Photovoltaic Program Review Meeting, University of Maine, Orono, 3-5 August 1976
4345	Application of Laser Technology to Atmospheric Monitoring	A. Mooradian	8th Materials Research Symposium, National Bureau of Standards, Washington, D.C., 20-24 September 1976
4360	Study of Perfect and Imperfect Surfaces Using Ultrahigh Vacuum Spectroscopy Techniques	H. J. Zeiger	Physics Colloquium, Syracuse University, Syracuse, New York, 16 September 1976

* Author not at Lincoln Laboratory.

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

The first two double-heterostructure GaInAsP/InP diode lasers to be life-tested have so far logged over 1000 and 600 hr, respectively, of continuous CW operation at room temperature without degradation. For both devices, the emission wavelength is 1.15 μm and the output powers are 2 and 4 mW, respectively. It is of particular interest that the lasers tested were fabricated from heterostructures grown on an InP substrate with a dislocation density of about 5×10^5 cm^{-2}, since GaAs/GaAlAs lasers grown on substrates with such a high dislocation density would have very short lifetimes.

For n^+-GaAs, a multiple-energy proton bombardment is shown to be superior to a single-energy bombardment in preparing uniform high-resistivity layers. An appropriate combination of a multiple-bombardment schedule followed by an anneal, which can be at a temperature as high as 500°C for carrier concentrations of 10^{18} cm^{-3}, can yield 10^6 to 10^8 Ω-cm layers in n^+-GaAs.

When low-dose n-type implants are made directly into Cr-doped GaAs, anomalous results are obtained on a large percentage of commercially available ingots. For some Cr-doped ingots, a thin n-type skin of "anomalous excess carriers" is observed after implantation, whereas a low activation of the implanted ions is observed in other ingots. On the ingots that show "excess carriers," an improved encapsulation procedure is described which can substantially reduce, and in some cases eliminate completely, the excess sheet concentration. On the ingots that show low activation, an ion-implantation damage-gettering technique is discussed which has been used to increase the activation of implanted ions to $\gtrsim$80 percent.

Schottky-barrier capacitance measurements have revealed that heating Br- and In-doped n-type CdTe wafers in the 75° to 300°C temperature range produces a large decrease in carrier concentration near the surface. This effect is presumably due to the outdiffusion of Cd and the concomitant formation of compensating defect centers.

Liquid-phase epitaxial films of $PbS_{1-x}Se_x$ on PbS substrates were grown using cooling rates in excess of 20°C/min. and initial growth temperatures of approximately 600°C. Liquidus data for growth solutions of $Pb_{1-y}S_y$ and $Pb_{1-y}(S_{0.7}Se_{0.3})_y$ are given in the temperature range of 580° to 670°C for y values in the 0.005 to 0.010 range, respectively.

II. QUANTUM ELECTRONICS

Calculations and preliminary experiments have been carried out on the feasibility of substituting NdLa pentaphosphate lasers for low-power Nd:YAG lasers using lamp or solar excitation.

With $CdGeAs_2$ and a passively Q-switched CO_2 laser pump, 1.9 W of average doubled power have been obtained. The second harmonic was generated in an antireflection coated crystal using 10.4 W of average input power and a pulse repetition rate of 20 kHz.

Two-photon resonantly enhanced tripling of CO_2 laser radiation in liquid CO mixtures has been observed. Using a tight focusing geometry, a power-conversion efficiency of 0.3 percent for the CO_2 R(6) line at 1069.01 cm^{-1} has been achieved in a CO-O_2 solution. The solvent

dependence of the CO two-photon resonance has been studied. Phasematching with an additional molecular constituent has been demonstrated.

A simple analytical model has been developed for the contribution of the vibration-rotation interaction to the linewidth of the isotropic two-photon resonance in simple molecular liquids. The results indicate that this process, which has not been included in recent theoretical calculations, contributes significantly to the observed linewidths. The evolution of the two-photon resonance peak intensity through the Doppler-broadened, pressure-broadened, and motionally narrowed regimes is illustrated.

Double-resonance spectroscopy of the ν_3 band of SF_6 has been carried out using a Q-switched CO_2 laser as the pump and a tunable PbSnTe diode laser as the probe. The effects of an intense optical field on rotational-vibrational transitions in the gas have been observed.

III. MATERIALS RESEARCH

In order to achieve accurate control of the thickness of the liquid-phase-epitaxial InP layers that are incorporated in GaInAsP/InP double-heterostructure diode lasers, this thickness has been determined as a function of the growth parameters. Since the results are consistent with a simplified model for diffusion-limited growth, they have been used to determine the diffusion coefficient of P in In-rich In-P solutions as a function of temperature between 550° and 680°C.

In developing a procedure for fabrication of GaInAsP/InP double-heterostructure diode lasers, a detailed study has been made of the liquid-phase-epitaxial growth of GaInAsP layers on InP substrates. No evidence has been found that lattice-matched epilayer compositions are favored in this system; the composition is a sensitive function of the growth parameters, which must therefore be closely controlled in order to obtain the lattice-matched GaInAsP layers required for efficient laser operation.

Laser emission at 1.58 μm has been obtained at about 80 K for double-heterostructure diodes with an active region of $Ga_{0.465}In_{0.535}As$ sandwiched between barrier layers of InP and $Ga_{0.20}In_{0.80}As_{0.48}P_{0.52}$. This emission wavelength is the longest that can be obtained for lattice-matched GaInAsP/InP diode lasers, since the active region composition is the P-free limit of the series of GaInAsP alloys with the same lattice constant as InP.

Seeded vertical Bridgman growth of $AgGaSe_2$, a material for nonlinear infrared applications, has reproducibly yielded crack-free single crystals with volumes of several cubic centimeters. Orienting the growth axis approximately parallel to the crystallographic c-axis has eliminated cracking that previously occurred because the thermal expansion coefficient of $AgGaSe_2$ is negative for directions within 25° of the c-axis.

Excellent selective black absorbers, with the high solar absorption and low infrared emittance needed for use in flat-plate solar collectors, have been prepared by employing RF sputtering to coat metal substrates with successive thin films of Cr_2O_3/Cr cermet and Cr_2O_3. Such thin-film composites deposited on Ni-coated stainless steel are stable in air at temperatures up to 300°C.

IV. MICROELECTRONICS

Large-area annular IMPATT diodes have been fabricated from GaAs having a lo-hi-lo impurity profile created by silicon ion implantation. Proton bombardment was used to define the annuli. Measurements of the thermal resistance of annular diodes and disk diodes of equivalent active area have indicated that the thermal resistance has been reduced by as much as 30 percent

by virtue of the annular geometry. An efficiency of 35 percent with an output power of 7.4 W has been achieved at 3.0 GHz, and another device has generated an output power of 12.1 W with an efficiency of 21.6 percent at 3.15 GHz.

Fabrication of the 100- × 400-cell CCD imaging sensors for the GEODSS (Ground Electro-Optical Deep Space Surveillance) Program has begun. Processing of the first set of silicon wafers has been completed, and approximately 13 percent of the devices on the wafers were free of gate-gate and gate-substrate shorts and were thus suitable for dynamic testing. Successful operation of one of these devices with electrical input signals has been achieved at the design goal data rate of 400 kHz.

A new transversal filter structure is described which uses charge-coupled device (CCD) technology and is capable of handling signals at data rates much higher than existing CCD implementations. This structure allows tap weights to be programmed as digital words, which can be stored on the device in static shift registers. A 32-stage prototype device has been designed and tested at data rates up to 20 MHz, which is the limit of our present clocking circuitry. Operation at even higher rates appears feasible.

A two's complement multiplier which can multiply two 8-bit signed numbers in less than 75 nsec has been fabricated in hybrid integrated circuit form using commercially available Schottky TTL dice. This project was undertaken in order to demonstrate the possible reduction in size of complex digital systems. The multiplier circuit was selected because it was felt to have greater applicability than a more specialized circuit. By putting eight dice into one package, a 6-to-1 reduction in system size over standard DIP packaging has been achieved.

The bias filter in a mixer diode circuit supplies DC bias to the mixer diode and provides the intermediate frequency output, while presenting an almost perfect reflection at the signal and local-oscillator frequencies. At centimeter wavelengths, the bias filters are usually made by using quarter-wavelength low- and high-impedance coaxial line sections to form a low-pass filter structure. However, at millimeter and submillimeter wavelengths, the low-pass bias filter cannot be constructed in coaxial form since the coaxial line dimensions become too small to fabricate by conventional machining operation. Bias filters for submillimeter wave mixers have been provided by an integral stripline filter which is incorporated into the diode package. The characteristics of these filters at submillimeter wavelengths were inferred from measurements made on dimensionally scaled filter models in the frequency range from 1.0 to 9.0 GHz. This use of scaled models is essential in evaluating mixer components for potential operation in the submillimeter wave region.

V. SURFACE-WAVE TECHNOLOGY

In order to maximize the Q in surface-acoustic-wave (SAW) resonators, it is necessary to minimize small residual losses. One such loss is due to scattering from surface waves into bulk waves at the edges of a reflection grating. This loss process has been suppressed by tapering the groove depth of successive grooves in a grating from zero up to the maximum depth. A taper which extends over a relatively short distance (typically 20 to 30 grooves) at the grating edge is adequate to significantly decrease the scattering loss. A simple ion-beam-etching technique has been developed for obtaining the tapers. With tapering, a Q of 80,000 has been obtained at 170 MHz on $LiNbO_3$, and a Q of 61,000 at 150 MHz on ST-quartz. These Qs are close to the material-loss limit.

A filter circuit which employs a pair of reflective-array compressors (RACs) has been developed. This unique circuit exploits the exceptional filter characteristics of RAC devices to obtain a bandpass filter with a bandwidth which is continuously variable over more than a 20:1 range. The bandwidth is varied by changing the frequency of a pair of oscillators in the filter circuit. A prototype circuit provides a bandwidth variable from 0.8 to 22 MHz, together with more than 50-dB out-of-band rejection.

Significant advances have been made in acoustoelectric memory-correlator technology. The memory correlator is a gap-coupled SAW device in which a matrix of freestanding diodes on a silicon strip is held in close proximity (~300-μm gap) to the surface of an $LiNbO_3$ SAW delay line. Interactions between the surface waves and the diodes provide a wide-band programmable analog matched filter. Improvements in the Schottky-diode arrays, the substrate geometry, and the mechanical assembly have yielded the desirable features of a stable, uniform response with wide bandwidth and long storage time (up to 100 msec). The use of LEDs for erasure of stored reference waveforms has been demonstrated. The major residual problem to be solved is the suppression of spurious signals in memory correlators.

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